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TAXONOMIC ISSUES IN RARE SPECIES PROTECTION

LISA A. STANDLEY

ABSTRACT

Taxonomy provides the basis for rare species protection by defining and naming the taxa eligible for listing and by providing biological information critical to plant protection. As endangered species laws become stronger (or more restrictive, depending on the point of view), it will become increasingly important that lists of endangered species be based on a solid scientific foundation and incorporate correct nomenclature. These factors are also important on a regional basis and facilitate coordinated interstate plant protection efforts. However, an examination of endangered species lists in the New England states has shown that 30% of the listed names demonstrate taxonomic inconsistency or error, and that additional biological problems of hybridity or asexual reproduction occur that may not be consistent with state endangered species definitions. The majority of the taxonomic problems noted in the New England rare flora are at the infraspecific level. Specific policy recommendations which arise from this study include the addition of synonyms to state endangered species lists, the formation of scientific advisory boards to assist state agencies with evaluating taxonomic changes, and increased support of taxonomic research dealing with rare species issues.

Key Words: Rare plant species, New England

INTRODUCTION

Taxonomy is fundamental to rare species protection, as this science determines the circumscription and name for a taxon. Taxa must be identified, delineated, and named before determination can be made whether they are rare and/or endangered. In order to implement necessary protective measures, starting with an official listing of rare and endangered species, these taxa must have valid and usable names. "Valid," as used here, means that names must conform to the International Rules of Nomenclature and reflect the best available biosystematic studies. "Usable" means that names, as stated on rare species lists, must also enable amateur and professional botanists to correctly characterize a plant's rare and endangered status.

Although taxonomy is the basis of rare species protection, taxonomic change is the source of some of the largest problems in conservation. Our knowledge and understanding of the evolutionary relationships of plants is incomplete, even in New England. As noted by Kartesz and Kartesz (1980), considerable taxonomic work is needed:

> "To untangle completely the collective nomenclatural web of truth, error, and synonymy which has accrued to the flora of North America will require years of detailed taxonomic research by individual specialists. Even in the Northeast, where vascular plant systematics has been an active interest for well over two centuries and where the amount of botanical exploration is unparalleled anywhere in the Western Hemisphere, many nomenclatural and taxonomic uncertainties still prevail."

Taxonomic revision benefits rare species management and protection efforts since it provides information on the biology of the rare species and their evolutionary relationships, and clarifies the taxonomic status. However, taxonomic revision creates problems for rare species protection when the name and/or status of each individual taxon undergoes change and revision. Lists of protected organisms need to keep pace with, and evaluate, taxonomic and nomenclatural changes.

These changes may create legal problems. If a listed rare taxon is protected under a certain name, that name must be correct and in conformance with other published names. Users of a rare species list must be able to identify plants and match their identification with a name on the protected list. A list cannot simply use the most recent name for a taxon, since this procedure would allow unscrupulous collectors to use an older name. As rare species are increasingly protected by legal statutes which affect private property, challenges to species listing are inevitable. Use of the appropriate taxonomic methods reinforces and supports efforts to provide protection to threatened flora.

In this paper, I examine the kinds of taxonomic and biological problems which exist in rare species lists published for the New England states, target research needed to solve some of these problems, and suggest other ways that scientists and regulators can interact to promote the preservation of rare taxa.

TAXONOMIC CONCEPTS

An interest in the diversity of plants is the primary reason why most botanists have taken up the study or protection of plants, as either a vocation or avocation. For most of us, the rare taxa of plants are especially intriguing for several reasons. Once one becomes familiar with the common species, searching out these real treasures of the plant kingdom becomes a challenge with intrinsic rewards. From a scientific point of view, rare taxa are of particular interest. Scientists approach the world by asking questions, and rare organisms provide the opportunity to ask a lot of questions: why is this thing rare? How, and from what, did it originate? What other species is it most closely related to? What aspects of its biology are unique?

The science of taxonomy is more often called Biosystematics, and its objective is the understanding of the pattern and process of evolution. Biological diversity itself, the numbers and kinds of organisms, is the pattern which results from this evolutionary process, understanding this pattern is critical to understanding the evolutionary process. Biosystematics involves three closely integrated aspects of scientific study.

Taxonomy is the science which attempts to determine the pattern resulting from evolution. A taxonomic study is based on compiling data from morphology, anatomy, cytology, genetics, reproductive biology and distribution, and analyzing these data to determine patterns of similarity and variation within and among populations. Data come from herbarium collections as well as living populations. The analysis may be based on an intuitive or computer-assisted analysis, but in either case it attempts to identify similar populations and to determine the similarities or disjunctions among population groups. The end result is a classification based on similarity and difference.

Nomenclature is the process by which each taxon identified and circumscribed by the taxonomic process is assigned a unique and correct name according to the current rules of nomenclature. This process is really not scientific, in the sense that no hypotheses are generated or tested, and relies on library and herbarium resources.

Biosystematics is the science which attempts to determine the evolutionary relationships among the taxa which are circumscribed in the taxonomic phase of the study. The data used may be the same as those used in taxonomy, but are here viewed from a different perspective: that of the analysis of characteristics as shared or not, as ancestral or derived. Data are evaluated, again either by intuitive analysis or assisted by computer programs.

This process refines the analysis of evolutionary pattern, connecting the taxonomic units in ancestor/descendant relationships. This stage enables good questions about evolutionary processes to be asked, since the results are evolutionary units and their relationships. Based on this level of information, scientists can proceed to study how the process of evolutionary divergence may have occurred.

The results of biosystematic/taxonomic studies are reported in scientific papers, monographs, theses, floras, and checklists. Such studies are fundamental to rare species protection, since they identify the taxa to be protected, assign names to be used in listing and identification, and provide biological data for protection and management.

How good are the taxonomic data available to us? Is a classification, whether published in a master's thesis or the most up-to-date regional flora, The Truth? We need always to keep in mind that the results of any taxonomic study are hypotheses, and the accuracy of one or another hypothesis depends on the kinds of evidence used, the types of analysis applied, and the competence of the researcher. Any taxonomy is subject to scrutiny, because it is a collection of scientific hypotheses. Classifications are constantly undergoing revision, as successive "generations" of botanists use older classifications as hypotheses to be tested using new evidence, new methods, new ways of thinking about plant evolution and classification. A classification scheme is not, and will never be, a stable or static entity, nor can we expect it to be such.

You should note that I have been using the word "taxon" rather than species. Taxon means, in a vernacular sense, a "kind" of a plant—"taxon" is any distinct biological unit, regardless of rank. Formal taxonomic ranks include family, genus, species, subspecies, and variety in addition to other less-used ranks such as subfamily, tribe, subgenus and section. Each rank has a generally-accepted meaning regarding the degree of similarity among members of that rank, and the amount of difference between different taxa at the same rank, although this variation depends to some extent on the plant family in question. For example, sections in the genus *Carex* are about as distinct as most genera in the Poaceae. We think of rare species lists as including and protecting most kinds of plant taxa; however, this assumption is not explicitly true for all rare species lists.

Most New England state laws are in fact inclusive of taxa at all ranks below the level of genus. In the Connecticut statute, " 'Species' means any species, subspecies, or variety of plant or animal, and includes any distinct population segment of any animal or plant." Massachusetts is similarly inclusive: " 'Species' means any distinct plant or animal population whose members interbreed or cross pollinate when mature and can include any subspecies or variety of plant or animal." New Hampshire also defines species to include "any species, subspecies, or variety of plant."

Rhode Island and Vermont also apparently include all ranks, although these are not named specifically. In the Rhode Island statute, " 'Endangered species' shall mean . . . any animal or plant." In Vermont, rare " 'Species' includes all subspecies of wildlife or wild plants and any other group of wildlife or wild plants of the same species, the members of which may interbreed when mature."

However, some laws include only some taxonomic ranks and generally exclude the plant rank "variety." The Maine statute does not provide a formal definition of species; however, all definitions refer to "a plant species or subspecies." The Federal statute defines endangered species as "Any species, including any subspecies of fish or wildlife or plant, and may include distinct population segment of any species of vertebrate, fish, or wildlife which interbreeds when mature." Ayensu (1984) has pointed out that the Federal list does currently include taxa at the varietal rank and notes that such listings may be subject to legal question. The U.S. Fish and Wildlife Service considers, since subspecies and varieties are essentially synonymous in meaning, that taxa named at the varietal rank are validly listed. None of these statutes explicitly provide endangered species status to hybrids, although the Rhode Island statute may be interpreted as including hybrids.

As a taxonomist, I see an additional problem with several of these definitions, particularly with the Connecticut, Vermont, Massachusetts, and Federal definitions, which allow protection of "any distinct population segment" (Vermont) or "any distinct population" (Massachusetts). These laws allow the protection of populations or segments of populations within species which have never received a formal taxonomic name. How does one identify and protect something which has no name? A more serious question concerns the evidence that the population or segment is sufficiently distinct to warrant protection. North-temperate plants have been fairly extensively studied during the last century. Our experience in New England has been that if there is even the slightest indication that a population is morphologically distinct, someone will have assigned it a name. Gray's Manual (Fernald, 1950) is full of such segregate taxa. If no name at any recognized taxonomic rank is available for a population or segment, can and should it be protected?

The concepts which lie behind the assignment of taxonomic ranks are important to rare species conservation. Managers and regulators need to know the basis of the classification with which they are dealing. In addition, several of the legal definitions of endangered species incorporate species concepts. Since so many of the endangered species statutes include taxonomic ranks, and in some cases explicitly define the biological characteristics of that rank, it is useful at this point to summarize some of the taxonomic concepts that underly the definitions of ranks.

Species Concepts

A taxonomist's work is based on a specific concept of what a species is; this concept provides a working theoretical framework. Numerous species concepts have been developed historically and have been the source of much debate. However, there is no ultimately correct definition of "species." Rather, different concepts are useful for different approaches to taxonomic or evolutionary studies (Liden and Oxelman, 1989).

The biological species concept (BSC), now often referred to as the isolation concept, is most familiar to non-scientists although often in an inaccurate form. At some stage of their education, most people have learned that, according to the biological species concept, two species cannot interbreed and produce fertile offspring, as shown by the horse/donkey/mule example. Mayr (1963) formulated the BSC to state that species are "groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups." This rather rigid and limited definition is probably the exception rather than the rule. While most species do not interbreed in nature due to some sort of isolating mechanism, speciation and reproductive isolation are evolutionarily independent (Endler, 1989). Adherence to this definition does allow recognition of cryptic species which differ by few phenetic characters but which are reproductively isolated due to genetic/behavioral traits. Populations of the same species may be more effectively isolated by distance than populations of different species may be isolated by other mechanisms. Natural hybridization in plants may be frequent, as evidenced in the fern genus *Dryopteris,* where *D. celsa, D. goldiana,* and *D. clintoniana* all are known to cross (Barrington et al., 1989).

The biological species concept carries another aspect, that of reproductive cohesion. Some authors segregate this aspect as the "cohesion" concept, but it is explicit in Mayr's more recent definition (1982) which states that a species is "a reproductive community of populations that occupies a distinct niche in nature." Members of a species reproduce themselves, and phenotypic cohesion among populations of a species may be maintained by genetics, reproductive constraints, or selection. This cohesiveness also carries an ecological component, indicating that species are ecologically distinct.

The application of a species concept which emphasizes cohesion, rather than isolation, is generally applicable to plants. It is also inclusive of plants which do not reproduce through normal sexual means by deleting the requirement that species are groups of actually or potentially interbreeding populations.

Although the biological species concept is, in some form, the theoretical basis for systematics, it is rarely used in practice as it requires extensive breeding studies and genetic studies of populations. Except in some long-term biosystematic studies, these data are generally not available. Reproductive continuity, and isolation, are inferred based on other characteristics and discontinuities between taxa. States which incorporate a biological species concept into protection statutes should be concerned about defending the listing of individual taxa based on reproductive biology.

Several endangered species laws (Federal, Massachusetts and Vermont) define an endangered species as "any population . . . whose members interbreed or cross-pollinate when mature." This definition is a strict and rather limited application of the cohesion concept of plant species, which I have not been able to locate anywhere in the literature dealing with species concepts; it effectively excludes all apomictic or asexual species or populations, as well as all species or populations which are exclusively autogamous (selfing). *Phegopteris connectilis,* listed in Rhode Island, is reported to be an apogamous tetraploid and should therefore be excluded from the list. *Antennaria petaloidea,* listed in Connecticut, is also apomictic and could not be listed in Massachusetts. Similarly, *Arnica lanceolata,* listed in New York, Maine, and New Hampshire, is an apomictic tetraploid which would be excluded from listing elsewhere in New England based on its lack of outbreeding. Many members of the rosaceous subfamily Maloideae, including *Amelanchier* and *Crataegus,* are at least facultative apomicts (Campbell and Dickinson, 1990). *Cratageus bicknellii,* although listed in Massachusetts, may not be legally eligible as a species based on research on other members of *Crataegus* section *Rotundifoliae* which has shown that these taxa are facultative apomicts (Smith and Phipps, 1988).

Most often in taxonomic practice, species are recognized using phenetic concepts. Species are recognized in part by the similarity among individuals and populations, observed as the low levels of variation present within and among populations. In simple terms, members of a species resemble each other more than they do members of any other group. The second key criterion is discontinuity between species. A species is everywhere distinct from other species, without extensive intermediate forms or hybrids. In general, this distinction is the practical method of taxonomy, supportable because it is based on kinds of evidence normally used in taxonomic studies. It is the logical result of the kinds of methods of analysis used in taxonomic studies, whether groups are created by piling herbarium specimens or by complex computer-aided multivariate analysis. When used in a thorough biosystematic study, the determination of taxa using phenetic methods is a valuable step in that it constructs a hypothesis which can be tested for the applicability of the isolation and cohesion concepts of species. Most, perhaps all, existing floras and checklists are based on phenetic species concepts and a phenetic-based taxonomy. Those endangered species laws which are based on phenetics, or which simply protect taxonomic categories without invoking species concepts, are legally defendable.

Infraspecific Taxa: Subspecies vs. Varieties

Generally, most taxonomists recognize taxa below the level of species, but historically, there have been some exceptions. Mackenzie (1931–35), in his treatment of *Carex* for the North American flora, only recognized taxa at the level of species. Two infraspecific taxonomic ranks are generally used, the subspecies and the variety. Variety is the older usage and originally referred to any minor variant of a species. This rank was used for populations or individuals which differed from the species in one or a few characters or which occurred in a distinct area or habitat.

Subspecies had its origin in zoological taxonomy and was used for "incipient species," geographic races generally distinct from other populations in a few characters but which intergraded in zones of contact. In these subspecies, viewed as incomplete stages in evolution, divergence was not complete and innate reproductive isolation had not been attained. The term "subspecies" has only recently, and not universally, been adopted for plants, although it is the only infraspecific rank used in zoological nomenclature.

The term "variety" has had mixed usage in plants. Originally, "variety" meant any marked variation within the species, not necessarily geographic, and was generally the only rank used for infraspecific taxa, whether variation had a geographic, ecological, or merely morphological basis. "Variety" was often used simply to indicate minor, not necessarily consistent, morphological variation. Currently, "variety" is used either as an equivalent to subspecies, connoting geographic variation, or as a sub-category under subspecies, denoting a minor, often ecological, variant.

As previously noted, the rank of "variety" generally lacks explicit legal protection under endangered species statutes. Federal law and many state laws only protect infraspecific taxa at the rank of subspecies. Since "variety" has long used as a synonym of subspecies, varieties are listed in both Federal and state endangered species lists, but this listing may not legally be defensible. Taxonomists concerned with rare plant protection should seriously consider taking up the use of the rank "subspecies" in place of "variety," to ensure that rare or endemic plant taxa are legally protected.

Hybrids

Despite the assumption of the isolation concept of speciation, plants do hybridize. Such hybrids may be sterile F_1 plants, swarms of backcrossed hybrids, or populations which may develop into new species. Reticulate evolution is not uncommon in plants, which may complicate cladistic analysis. Hybrid species (nothospecies) are regarded as distinct evolutionary species (Barrington et al., 1989), although differing from "normal" species which originate by divergence.

Nomenclatural rules allow us to recognize hybrids in three ways. A hybrid may be given a unique specific epithet, using standard nomenclatural format; *Scirpus peckii* is an example. This name conveys no useful information whatsoever. Alternatively, a hybrid may be designated as a nothospecies by the use of an "×" preceding the specific epithet, as in *Prenanthes* ×*mainensis*. This format at least conveys the warning that the taxon is a hybrid. Best, a hybrid may be designated as a combination of the names of its progenitor species, as in *Carex crinita* × *C. gynandra*. The last method conveys the most information, and is therefore the method of choice, but is not preferred by some compliers of rare species lists (Johnson, 1988) since this method is often used for F_1 hybrids.

There are substantial biological problems with hybrids as named in regional floras and as listed in state endangered species lists; for most of these taxa, virtually no information is available. A hybrid name may represent a single collection of a sterile F_1 plant, a backcrossed population, a new species derived from hybridization, or simply a variant individual, clone, or population within a morphologically variable species (Snaydon, 1984).

Taxonomic research is critical to provide sufficient biological information to enable regulators to determine whether a hybrid taxon should be listed and protected. I will not get into the questions of criteria and priorities for listing at this point, but simply examine the issues of hybrids. Most hybrid taxa have been named based on phenetics, generally restricted to morphology.

Recent research within the maritime species of *Carex* sect. *Phacocystis* (Cayouette and Morisset, 1986; Standley, 1990) has shown that several species within this group are of hybrid origin, based on analysis of chromosomes and genetics, and has clarified that several named taxa are sporadic F_1 hybrids. The hybrid species may be treated as a nothospecies, including all of the F_2 backcrosses, or as a distinct species which excludes the backcrosses, each of which has been named. For example, *Carex recta* (*C. aquatilis* × *C. paleacea*) is listed by Massachusetts but is incorrectly listed as *C. salina* var. *kattegatensis* by Maine.

There are a number of hybrids included in the New England endangered species lists, although none of the state endangered species definitions includes hybrids. Little or no biological information is available for any of these listed taxa, which include *Asplenium* ×*ebenoides* (known to be sterile), *Carex* ×*mainensis*, *Carex* ×*trichina*, *Scirpus peckii*, *Amelanchier nantucketensis*, and *Prenanthes* ×*mainensis*. We do not know whether any of these named hybrids are capable of sexual or asexual reproduction or whether their hybrid status has been proven or is merely hypothetical.

A second issue which may arise when dealing with hybridization in listed plant taxa concerns the application of the Biological Species Concept. Strict application of the BSC implies that "good" species do not hybridize with other taxa under normal circumstances. As pointed out previously, many plant taxa do occasionally hybridize in nature, and this behavior may be the source of new genetic combinations and new species. None of the New England rare species protection acts, nor the Federal Act, invokes the BSC in all of its rigor. Occasional hybridization, therefore, should not be a biological or legal issue which impedes listing of rare taxa.

TAXONOMIC AND NOMENCLATURAL PROBLEMS IN NEW ENGLAND ENDANGERED SPECIES LISTS

For this symposium, I have compiled the endangered species lists of all of the New England states and New York and included Federally listed species. This compilation was done for three families of angiosperms, the Cyperaceae, Rosaceae, and Asteraceae. Species of leptosporangiate ferns were also examined. The compiled list provided the name under which each taxon is listed, the states in which it is listed, and the name which is used for that taxon in recent floristic treatments for the region. Specifically, each name was checked in Gleason and Cronquist (1991), Fernald (1950), and Ogden (1981).

The majority of species listed present no taxonomic problems. Of the 320 names listed, almost 70% were listed by the same name, at the same rank, on the state lists and in the floras referenced. However, over 30% of the listed names were identified as having taxonomic or nomenclatural problems, including differences among state lists or between state lists and published floras in name, rank, or taxonomic status. In general, the problems in the New England flora are similar to those described by Johnson

(1988) for palms. Although there are fewer difficulties with poorly described genera here, major problems are posed by taxa below the species level and by hybrids in both the poorly-studied tropical palms and the comparatively well-known temperate flora.

Three classes of taxonomic problems are recognized in this analysis. The first problem is a change in name, at the same rank: the taxon is recognized as a distinct entity, but placed in a different genus, kept within the same genus under a different name, or kept within the same species under a different infraspecific epithet. The second class of problem is that of a change in rank, in which the taxon is recognized as a distinct entity but is considered by some authors to be a distinct species and by others to be a subspecies or variety. The final class is that of taxonomic distinctness, the classic "lumping or splitting" problem, in which some authors have recognized a group of populations as a distinct taxon at either the specific or infraspecific rank, while other authors have not found the group of populations to be sufficiently distinct to warrant recognition at any rank. The list was first analyzed by families, then by type of taxonomic problem.

Within the ferns, approximately 30% of the listed names present problems. These include name changes at the generic level, changes in rank, and synonymy. Several instances were noted of biological problems, including hybridization and apospory.

The genus *Carex* predominates in the Cyperaceae and accounts for 60% of the listed names of endangered taxa. Taxonomic problems in rare New England *Carex* were treated by Reznicek (1989) at the 1988 NEBC symposium, and account for only 28% of the problems within the family. Overall, 30% of the listed names in the Cyperaceae present difficulties; most problems are in synonymy and changes in rank. The family presents surprisingly few biological problems, with few hybrids and no known asexual species. The spikerushes (*Eleocharis*) present the greatest proportion of taxonomic problems, with 45% of the listed names for this genus in question.

The Rosaceae had the highest overall percentage of taxonomic problems, including 50% of the listed names. Most problems are identified as synonymy at the infraspecific level, or as changes in rank. These problems are complex, however, as most taxa which present difficulties have been treated as infraspecific taxa, as distinct species, or have been lumped with different species by different authors. Biological problems, particularly asexuality, are frequent; for example, *Crataegus bicknellii* (endemic to Nantucket) may be a distinct species (Kruschke, 1965), a variety of *C. chrysocarpa* (Fernald, 1950), or an apomictic clone of *C. chrysocarpa* with no taxonomic rank (Gleason and Cronquist, 1991).

The Asteraceae was comparable to the Cyperaceae in the incidence of taxonomic problems, with approximately 30% of the listed names in question. The most common issues were generic shifts and synonymy at the infraspecific level. Asexual taxa are frequent, although hybrids were not. Interestingly, *Bidens* appears to have the highest incidence of taxonomic difficulty within the family. Thirteen names are listed (although one, *B. coronaria,* appears to be a typographic error), with seven identified as problematic. The *Bidens eatonii, B. heterodoxa,* and *B. hyperborea* complexes all appear to need good taxonomic work. This group also illustrates problems between state lists: Massachusetts and Maine protect *B. eatonii* (no variety listed), while Connecticut protects two varieties, *B. eatonii* var. *major* and *B. eatonii* var. *simulans* based on the classification in Fernald (1950).

TYPES OF TAXONOMIC PROBLEMS

Generic Shifts at Same Rank

Some problems in lists occur when species have been transferred from one genus to another by a taxonomist who determines that two genera are not distinct or who recognizes that a group of species formerly placed in one genus represents a distinct genus. This important taxonomic decision is made at the generic level using the same data and the same process as at the species level. This problem may also occur when a nomenclatural study reveals that an error has been made in the selection of a generic name, but it is relatively rare with only 6 occurrences among the 320 names listed.

However, some inconsistencies do occur between state lists and between rare species lists and published references. *Diplazium pycnocarpon,* listed in New Hampshire, is listed as *Athyrium pycnocarpon* in Connecticut, but is referred to as *Thelypteris pycnocarpon* in Gleason and Cronquist (1991). Here we have the same taxon, listed under different names in different states, and also differing from the name used in the most recent regional flora. The coastal plain pond sedge genus *Psilocarya* includes *P.*

nitens and *P. scirpoides,* both listed in New York, Massachusetts, Rhode Island, and Connecticut. This genus has been included in the beak-rush genus *Rhynchospora* according to recent taxonomic studies (Gleason and Cronquist, 1991).

As another example, *Aster ptarmicoides* is listed by New Hampshire, but is listed in Massachusetts and Connecticut as *Solidago ptarmicoides.* Cronquist (Gleason and Cronquist, 1991) agrees that this species is a goldenrod rather than an aster. In general, this taxonomic problem is not difficult for regulators to solve and may not require taxonomic study; the listing of the same taxon under different generic names may be solved simply by including all major synonyms in the endangered species list.

Change in Specific Epithet

In this second class of taxonomic problem, different lists or floras maintain the same taxon at the species level, but treat it under different names. Generally, this situation is the result of nomenclatural research which has shown an incorrect name used at some previous date and is not a common problem in endangered species listing, occurring at most six times (less than 2%) within the list compiled here. One example is provided in *Carex,* where *Carex walteriana* var. *brevis,* listed in Rhode Island, should be *C. striata* var. *brevis,* as listed in Massachusetts. The listing of frequently used synonyms would reduce this problem.

Change in Varietal/Subspecific Epithet

This problem is similar to the preceding two, but at the infraspecific level. I have included in this category changes in name which may be required when infraspecific taxa are transferred from varietal rank to that of subspecies. This problem is infrequent, occurring in less than 2% of the listed names. *Rosa acicularis* ssp. *sayi* is listed by New York and is the preferred usage in Gleason and Cronquist (1991). However, these authors note that, if treated as a variety, the correct name would be *Rosa acicularis* var. *bourgeauiana.* Massachusetts, New Hampshire and Vermont avoid the issue by listing *Rosa acicularis,* without mention of which, if any, of the infraspecific taxa are included. Similarly, *Prunus pumila* var. *susquehana,* listed in Rhode Island, is treated by Gleason and Cronquist as *Prunus pumila* var. *cuneata.*

The listing of major synonyms would enable users to determine that these names refer to the same taxon, with the same listed rank.

Changes in Rank

The second most common type of taxonomic problem, and a close tie for first place, is taxonomic change caused by a change in rank. The taxon is consistently recognized as distinct, but is placed by some authors at the infraspecific level and raised by others to the specific level. Eighteen occurrences of this problem were noted, for an average frequency of 6%. This problem is not a critical taxonomic one, unless it occurs in a state which does not legally protect varieties, and can easily be solved by including synonymy. Mayr (1982) and others have pointed out that the decision whether to call a taxon a species or subspecies is arbitrary. In phylogenetic systematics, all taxa of all ranks have the same evolutionary status, i.e., they are monophyletic units which have a shared apomorphy (Liden and Oxelman, 1989). Examples include *Carex woodii* (Connecticut) which is also recognized as *C. tetanica* var. *woodii*; *Eriophorum spissum* (Connecticut) and *Eriophorum vaginatum* var. *spissum* (Rhode Island, also in Cronquist); *Antennaria petaloidea* (Connecticut), treated as a variety (*Antennaria neglecta* var. *petaloidea*) by Cronquist; and *Tanacetum bipinnatum* ssp. *huronense* (Maine), treated as a separate species, *T. huronense,* by Cronquist (Gleason and Cronquist, 1991).

Lumping and/or Splitting

Most taxonomic problems in listings arise because of what is generally referred to as "lumping" or "splitting," that is, changes in which taxa are not maintained as distinct (lumping), or in which new segregate taxa are found to exist (splitting). These changed designations include the majority of taxonomic problems noted in the compiled regional lists and may include changes at the specific or infraspecific levels. I will not delve into the reasons for these taxonomic changes, except to note that whether the result of a taxonomic study is "lumping" or "splitting" depends on the methodology used in the taxonomic study, the amount of difference between taxa which the investigator considered significant, and the species concept used by the investigator.

At the rank of species, 16 occurrences of lumping or splitting were noted, accounting for 16% of all taxonomic problems. One example is provided by *Carex garberi* and *C. aurea*. Although several states (New York, New Hampshire, Vermont, Minnesota) consider *C. garberi* to be endangered, and a Federal Candidate species, Cronquist (Gleason and Cronquist, 1991) considers it a synonym of the widespread *C. aurea*. However, a recent study by Katz et al. (1988) provided evidence that these are distinct species based on a multivariate study of morphological characters and that the listing of *Carex garberi* is valid.

At the infraspecific rank, changed designations are the most common problem and are recorded for 31 of the 320 listed names. Taxa are recognized by some states or floras as distinct taxa at the varietal or subspecific level, but other treatments recognize no infraspecific variation. As examples, New York lists *Scleria reticularis* var. *pubescens*, while Rhode Island (in agreement with Cronquist) lists only *Scleria reticularis*. Several states list *Waldsteinia fragarioides* (Massachusetts, Maine, Connecticut, New Hampshire), although recent floras recognize this taxon to be a variety (var. *fragarioides*) distinct from the European variety. Maine and New York (in agreement with Cronquist) protect *Bidens hyperborea*, while Massachusetts lists only the segregate *B. hyperborea* ssp. *colpophila*.

Several instances were noted of species which are recognized in recent floras to include two or more infraspecific taxa, yet state endangered species lists include only the species, with no mention of the variety or subspecies. This oversight creates a dilemma for the user. For example, does Maine's *Prenanthes racemosa* refer only to the autonym *P. racemosa* var. *racemosa*, or does it also include the segregate *P. racemosa* var. *multiflora*? Massachusetts lists, enigmatically, "*Scleria pauciflora* (2 varieties)." Which two? Fernald (1950) lists *S. pauciflora* var. *caroliniana* and *S. pauciflora* var. *kansana*, but omits the autonym var. *pauciflora*, which must also exist. Cronquist (Gleason and Cronquist, 1991) does not recognize any infraspecific taxa.

Other examples are more complex and involve taxa which are variously treated as a distinct species, an infraspecific taxon, or lumped. These designations appear to occur most frequently in the Rosaceae, as shown by the following examples: *Potentilla pensylvanica* var. *pectinata* (Vermont), *P. pectinata* (Fernald, 1950), or *P. pensylvanica* var. *bipinnatifida* (Gleason and Cronquist, 1991); *Prunus gravesii* (Connecticut), *P. maritima* var. *gravesii* (Federal Candidate), and *P. maritima* (Cronquist).

RECOMMENDATIONS FOR POLICY COPING WITH TAXONOMIC CHANGE

Rare species managers or regulators are constantly faced with taxonomic change as a result of the steady production of new monographic treatments, checklists and floras. Perhaps "constantly" is an exaggeration, since the investigation of systematics of north-temperate taxa is proceeding rather slowly at present. Still, name changes and new taxa appear and must be dealt with if lists of endangered species are to remain up-to-date and accurate. Coping with this change and updating lists is a difficult and time-consuming task. Most of the New England states relied, in their original listings, on *The Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland* (Kartesz and Kartesz, 1980). This list provides the most recently published accepted name for each taxon, i.e., the result of the most recent taxonomic hypothesis, and lists all taxa published prior to 1980.

The use of such a standardized list solves some problems by basing an endangered species list on a single reference, but fixes the list in time without provisions for change. Since taxonomy and classifications are subject to change based on new research, new methodologies and new frames of reference, an endangered species list needs to be able to accommodate change. As noted by Kartesz and Kartesz (1980), taxonomic revision is needed even in our region.

The simplest way to accommodate taxonomic change without requiring extensive amendment to endangered species lists would be to include all major synonyms in the list, particularly those used in *Gray's Manual of Botany* (Fernald, 1950), *The New Britton and Brown* (Gleason, 1952), *The Manual of Vascular Plants* (Gleason and Cronquist, 1991), and *The Flora of New England* (Seymour, 1982). This procedure would ensure that the endangered species list does not simply use the most recently published name for a taxon, but would incorporate all names in common use and allow for taxonomic changes. If a new flora or monograph were published which used a new name or new combination, the older name would be incorporated by reference. The U.S. Fish and

Wildlife Service does include major synonyms in the annually published "Endangered and Threatened Wildlife and Plants; Review of Plant Taxa for Listing as Endangered or Threatened Species," and provides a discussion of taxonomic issues in the published Determination of Endangered Status, which is the official agency action required to place a species on the Federal list. At the state level, however, considerations of synonymy are rarely included.

There is a real need for endangered species lists to be usable and accessible to academic, amateur and conservation botanists, not all of whom have access to Kartesz and Kartesz (1980). If the endangered species list provides only one name without synonyms, the average user may be stumped and the list will not be sufficiently flexible to accommodate changes. For example, if an avid amateur in New York identifies a plant using *Gray's Manual* as *Potentilla egedei* var. *groenlandica*, how is this botanist to know that the plant is listed as endangered, since the New York list refers to it as *Potentilla anserina* ssp. *pacifica*? In Maine, if a coastal sedge is identified as *Carex recta* by a botanist using the new Gleason and Cronquist Manual, how is this person to know that the plant is listed as endangered under the name of *Carex salina* var. *kattegatensis*? A list which provided synonymies would avoid such problems by enabling users to readily determine species identities.

The synonym problem is evident in the use of different names for the same taxon by different states. We have already discussed some of these which result from name changes at the generic or species level: *Athryium pycnocarpon* in Connecticut vs. *Diplazium pycnocarpon* in New Hampshire; *Carex striata* in Massachusetts vs. *Carex walteriana* in Rhode Island; *Eleocharis parviflora* in Maine and Vermont vs. *E. parviflora* var. *fernaldii* in Massachusetts. Without a thorough synonymy, it is difficult to collate the state lists and accurately determine how many taxa are listed as endangered in the region. In my examination of these lists, for the four families treated, I have found 320 names, but these probably represent only 290 taxa. Johnson (1988) proposed that *no* infraspecific taxa be listed, but that the species be listed if any infraspecific taxa were thought to be endangered. This option, in his opinion, would reduce the number of taxa to be listed and would avoid overstating the number of truly threatened species in cases of taxonomic uncertainty. There may be reason to adopt this strategy with regard to the New England flora. To cite a previous example, consider *Bidens eatonii*: since the existence of distinct varieties is possible but not proven, simply listing the species will provide protection to all populations of this taxon.

One type of taxonomic change is that which results in combining two taxa into a single species, only one of which was previously listed. For example, *Solidago purshii* is listed by New Hampshire as a rare species, but it has recently been combined with the more common *S. uliginosa* (Gleason and Cronquist, 1991). How do endangered species program managers make the decision whether to drop *Solidago purshii* from listing?

A second type of taxonomic changes is the change in rank, for example, in which a taxon previously listed as endangered at the species rank is reduced to a variety of a non-listed species. *Petasites palmatus* has recently been reduced to a variety of the widespread *P. frigidus* var. *palmatus*. An amendment to the list, or provision of synonymy, should solve this problem—unless the state in question has a statute which does not include taxa at the varietal level.

Endangered species program managers need strategies for updating lists and evaluating taxonomic changes. Most programs and lists reflect the names used in Kartesz and Kartesz (1980), which are the most recently published names of taxa, thereby assuming that the most recently published name is correct, an assumption that may present problems. Taxonomists aren't always right: evidence may not be adequate, evaluation may be flawed or methods may not have been applied correctly. Simply because a name has been published does not necessarily mean that it is closer to the "truth" than previous taxonomic treatments. The taxonomist may not know the group well, may not have studied the problem over the entire range of the group or may have used only local evidence or only herbarium material. In practice, published taxonomic changes are carefully considered and evaluated by the scientific community and either adopted or ignored, depending on the quality of the evidence presented in the original publication, a practice which may require several years before a name or rank change is fully accepted.

Each name change needs to be evaluated on a case-by-case basis before adoption. Since endangered species program managers do not have the time to do this and frequently lack expertise among their staff and interns, I suggest that each state develop a panel of taxonomic experts which is responsible for keeping up with and evaluating nomenclatural and taxonomic changes. Each proposed change should be examined with regard to types of data used, methods used to interpret and analyze data, knowledge and expertise of the taxonomist, use of natural populations vs. herbarium collections, and systematic concepts used by the taxonomist.

Programs need to have in place a method for regular updating of lists. In some states, this updating will be as simple as publishing a revised list annually and ensuring that the program budget can support such a publication. In other states, rare species list revision will require publication of a draft for public review prior to official listing; this review carries certain dangers and subjects all listed taxa to comment and perhaps challenge.

Endangered species program managers and scientists need to increase interactions. Program managers need to understand scientific perspectives on rare species taxonomy and systematics, just as scientists need to understand the objectives and information requirements of endangered species protection. Systematics and ecologists can provide important information regarding criteria for listing as well as reproductive, genetic or autecological information necessary for the development of protection, restoration or management strategies. One contribution that the scientific community, perhaps via the New England Botanical Club, could make that would assist rare species managers would be to produce and maintain a data base of specialists in different plant groups.

INCREASING RESEARCH EFFORTS

Setting Research Priorities

Examination of endangered species lists reveals a large number of taxonomic problems which require research to address either taxonomic or systematic issues. Endangered species program managers, or their scientific advisory panels, can be effective if they set research priorities. My assessment of endangered species lists has shown that the major taxonomic problems concerning New England's rare taxa can be divided into four categories:

1. Does the taxon really exist as a distinct entity? Is this taxon,

whether ranked as a species, subspecies or variety, phenetically and/or biologically distinct from other taxa with which it has been combined, or from which it may have recently been split? In essence, this category of research addresses the validity of taxonomic lumping or splitting, and is crucial to the development of a scientifically valid endangered species list.

2. At what taxonomic level should a taxon be recognized? If a taxon is distinct, but there is disagreement in the published literature as to its rank as a species, subspecies or variety, research is needed to clarify the taxonomic rank. In some states this research may not be as critical since the taxon may be protected regardless of rank. However, if a state's endangered species statute does not explicitly include the rank of variety, taxonomic rank may also be critical to a scientifically valid list.
3. Are listed hybrids valid taxa? Are these taxa sporadic, sterile F_1 hybrids of no real systematic or evolutionary value, or are these established populations of reproducing F_2 plants, or are they stabilized taxa of hybrid origin? These questions are also important in rare species protection. A list which is defensible should not include questionable taxa or sterile F_1 hybrids. Some state statutes do not allow rare species status to be extended to hybrids. If such hybrids are to be listed and protected, it is important to understand their origins, genetics and reproductive potential.
4. What taxonomic groups need study? Based on my survey of the state lists, I can make some suggestions for research efforts that would be valuable for rare species listing and management, dealing with all three of these research goals. Groups or taxa which need taxonomic or biosystematic study include, but are certainly not limited to the following: the *Carex brevior/molesta/merritt-fernaldii* complex; *Carex katahdinensis*; *Eleocharis*, particularly *Eleocharis engelmanii/ovata* and *Eleocharis pauciflora/E. pauciflora* var. *fernaldii*; *Potentilla pensylvanica/pectinata*; *Prunus pumila* complex; *Amelanchier sanguinea/humilis*; *Artemisia campestris*; *Bidens eatonii*, *Bidens heterodoxa* and *Bidens hyperborea*; *Carex ×mainensis* and *C. ×trichina*; *Scirpus peckii*; *Prenanthes*, especially *Prenanthes ×mainensis*.

Research Methodologies

Once research priorities have been established, endangered species program managers would need to determine the appropriate research methodologies to answer the questions needed. In general, taxonomic research needs to be carried out using as many methods as possible to ensure that all appropriate data are collected and analyzed. Studies should include use of herbarium material and natural populations; data should be collected on morphology, anatomy, cytology and genetics; data should be analyzed using both intuitive and computer-assisted techniques. Studies of breeding systems and reproduction may be appropriate to answer systematic and management questions. Finally, I would suggest that a study should include the entire complex over its entire geographic range in order to provide valid answers. Taxonomic studies which include only the taxa, or populations, contained within a single state are unlikely to provide the information needed to evaluate the status or rank of a taxon. The majority of taxa listed as endangered in New England are more widely distributed taxa at the limits of their range, rather than local endemics.

Examination of the biosystematic literature shows that north-temperate species, particularly rare taxa, are understudied despite opinions to the contrary. We have little or no data on genetic variation, the kind and extent of differences between related taxa, population structure, factors which contribute to rarity, reproductive biology, or evolutionary relationships for the majority of taxa. All of this information is needed to develop strategies that are effective in protecting and managing rare plant species (Bramwell, 1984). Too often our knowledge of rare species is limited to information available on herbarium sheets; there are some counterexamples, but these are infrequent. Pleasants and Wendel (1989) determined the evolutionary relationships and reproductive biology of the rare *Erythronium propullans* using genetic studies. One useful result was the discovery that this rare species consists of several widespread clones. Standley and Dudley (1991) determined the extent and pattern of genetic variation in the rare sedge, *Carex polymorpha,* and elucidated the relationship between canopy and population vigor. Based on this information, managers can target populations for protection and develop ecological management strategies. Other examples are few, and a reader is struck by the gaps in our knowledge of rare plant biology. Biosystematic research can provide the knowledge of biology, evolutionary history and demographic patterns needed in order to understand the causes and consequences of rarity (Fiedler, 1986).

A more general research priority for New England might be to produce the kind of comprehensive biological treatment of rare taxa that has been produced for Minnesota (Coffin and Pfannmuller, 1988) or Canada (Argus and Pryer, 1990). Both volumes provide a full synonymy for each listed species and examine its status in other states. The Minnesota volume in addition provides detailed information on the ecology, distribution and biology of each species, with references to all published literature. Such a volume would be tremendously valuable in New England and would require that at least a minimal amount of taxonomic/biosystematic research be performed for each listed species.

Funding Research

Basic taxonomic or biosystematic studies of north-temperate species, focussing on problems at or below the species level, are not a priority for federal grant funding. State research funds are often limited or unavailable due to the local economy. However, such research costs money for supplies (genetic studies require costly chemicals), travel, computer time, student assistance, greenhouse space and postage for herbarium loans. A thorough taxonomic study of a species complex could require at least ten thousand dollars in research funds and would take at least two years. I have probably been optimistic on both counts. State and federal endangered species programs need to provide funds for systematic research and need to carefully assess their research needs and priorities if they are to produce rare species lists which will withstand legal challenge and adequately protect taxa by enabling all users to readily identify listed taxa.

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